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Book Review

Picture Processing by Computer. By AZRIEL ROSENFELD. Academic Press, New York, 1969. x + 196 pp. $11.50.

Technological progress gives birth to a new area of science. However, to give a unifying theoretical structure to fragmentary scientific findings in such a new field, one needs a mind provided with both rich imagination and love of systematic thinking over and above the necessary mathematical training. Professor Rosenfeld has proved to have such an unusual gift by writing this book which has succeeded in almost giving the appearance of a self-contained branch of science to the collection of brand new know-hows connected with mechanical processing of pictures.

The background and goals of the work described in this book is clearly summarized in the first paragraph of the Preface. The author writes: "Over the past 15 years, much effort has been devoted to developing methods of processing pictorial information by computer. This work has had a number of different goals, among them television bandwidth compression, image 'enhancement' and 'restoration,' and pictorial pattern recognition. Most of the research in the field of picture processing has been directed toward the solution of specific problems, usually involving particular classes of pictures; but a body of 'general-purpose' picture processing techniques is gradually being built up. This book treats the subject of picture processing from a primarily technique-oriented, rather than problem-oriented, standpoint." The problem of computer-generated pictures is kept outside the scope of the book.

Chapter 1, entitled "Picture and Picture Processing," defines a picture as a function (representing gray-level) of two arguments, and asserts that such a function is usually indistinguishable from a function that is well-behaved in various senses so that the use of purely mathematical operations on it is justified. In the last section of Chapter 1, three major areas of picture processing are mentioned: (a) Encoding and approximation; (b) Filtering, restoration and enhancement; and (c) Pattern recognition and picture description. These are the major topics of the book.

Chapter 2 discusses "Picture Coding." After a short introduction on the elementary information theory, the method of (nonerror-correcting) coding is applied to the succession of quantized gray levels.

"Approximation of Pictures" dealt with in Chapter 3 has one feature in common with "Picture Coding" in that it also results in "compression," but decreases the information content. If the lost information is of an insignificant nature, we do not suffer from degradation of the picture. Two basic tools of approximation discussed in this chapter are sampling and quantization. The optical method of frequency filtering will be discussed later.

Chapter 4 entitled "Position-Invariant Operation on Picture: 1, Theory," starts with the definition of a "position-invariant operation" as a transformation of a picture function into a picture function that commutes with the shifting operation. The reader who is baffled by this abstract concept will soon be surprised by the richness of its applications. One of the most important theorems, to the effect that any position-

invariant linear operation is a convolution operation, is unceremoniously introduced (even without being called a theorem) in the middle of the chapter. The Fourier transformation is introduced in this chapter, although it is not a position-invariant operation. The reason is obviously that convolution becomes multiplication in terms of the Fourier transforms.

Chapter 5 is the "Implementations" of the theoretical results of Chapter 4. The reader who has had enough of mathematics can breathe in this chapter. It introduces various physical methods of picture operations, departing somewhat from the title of the book, which says "processing by *computer*." Everybody will be fascinated by the description of the newest results in the "Fourier optics."

Chapter 6 is the "Applications" of the idea of position-invariant operations. One reads about theoretical and experimental results regarding "template matching." This chapter also includes discussions of frequency filtering, smoothing, sharpening, etc.

Chapter 7 is entitled "Picture Properties and Pictorial Recognition." The author avoids discussing the various general methods of pattern recognition, and after giving a short characterization of pattern recognition problems, proceeds to treat the various "properties" that can be extracted from a picture, such as local, textural, linear, random properties, etc.

Chapter 8, entitled "Picture Segmentation," is a necessary preparation for Chapter 10, which deals with the problem of description of a picture. Such a description refers to constituent parts (the author gives them the fancy name "subsets") and specifies their individual properties and their relations. For this reason, recognition of constituent parts is the first step toward the "description." The chapter mentions many known methods and explains them clearly, but the state of the art leaves still much to be desired. There is no simple mechanical way of recognizing a nose on a portrait.

Chapter 9 on "Geometrical Properties of Picture Subsets" is a continuation of Chapter 8 preparing the road to the last chapter. Once a "subset" is singled out by one or several of the methods explained in Chapter 8, its properties must be measured or computed. There are topological properties, metric properties, and properties that are functions of a single variable.

Chapter 10, entitled "Picture Description and Picture Languages," is, so to speak, the climax of the entire book, discussing the "description" of a picture, in particular, the method of specifying the way in which the subsets are composed into a picture. Probably because this is the field in which the author is presently active, the exposition is very vivid and to the point. Different from other surveys on this topic which usually start with impressing the reader by invoking the prestigious linguistic theory à la Chomsky, this book starts with simple examples and gradually leads to the concept of picture language. It can be perceived between lines that the author's concept of picture language tries to go beyond the bounds of the usual grammatical theory. The author is too modest to mention the newest results of his own theory, but the reader would have appreciated it if he had done so.

If accuracy, lucidity, comprehensiveness, and succinctness are the criteria of a book of this kind, this book certainly receives the mark "excellent" on every account. If we add readability to the criteria, the evaluation will depend on the background of the reader (a good training in college mathematics is necessary to read this book). Those who are accustomed to the abstract, redundancy-free style of mathematical papers will find the book quite readable and pleasant. But those who like to have an abundance

of "apéritifs" and "digestifs" combined with verbose explanations appealing to "intuition," will find the book less than entertaining.

The book has a comprehensive up-to-date bibliography of pertinent papers at the end of each section, which is very valuable. There are a generous number of beautiful photographic illustrations and good black-and-white figures. Many sections are followed by a small number of exercises. Some of them are genuine exercises, but many of them are the author's device for reducing the size of the book, letting the reader fill in the materials. The occasional digressions belonging to a different level are carefully indented, but it is questionable whether such a rigorous separation of digressions from the main text was really necessary.

The reviewer personnally would have welcomed more of the digressions. For instance, in connection with the use of the Laplacian to discover edges, a paragraph or two describing the interesting historical background of this method involving Mach and von Békésy would have made the chapter much more palatable. By the same token, the psychological shock that some of the unfamiliar readers may have to go through reading the highly mathematical definition of position-invariant operations could have been alleviated by a few concrete examples of time-invariant operations in the one-dimensional case at the beginning of the chapter.

This is not a criticism, but the word "function" is somewhat overworked in this book. It might help to distinguish "functional" and "function," to avoid possible confusion. One may state that a picture is a function, and a property is a functional of such a function, and a convolution is a two-parameter functional, etc. In discussion of indistinguishability of two pictures, one may introduce the basic indeterminacy in the accuracy of position variables. In other words, the picture is from the beginning a two-dimensional array of locally averaged grayness, which is a kind of functional of the sharply defined grayness function.

To avoid misunderstanding let me repeat that the greatest merit of this book is its conciseness. This style results in the surprisingly few number of pages which contain so much of the contents. One of the necessary consequences of this is, of course, that the price of the book was kept within a reasonable range. What made this economy in reading time and in money possible was evidently a hard and high-powered mental effort on the part of the author. For this, every reader will be grateful to Dr. Azriel Rosenfeld.

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